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CENTRAL LIQUEFIER FOR THE FERMILAB TEVATRON

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We would like to describe briefly the Fermilab Central Helium Liquefier. The main components are the compressors, the purification system, and the cold box, whose characteristics will be discussed here; and the control and monitoring system, which will be described elsewhere.

The Compressors

The design characteristics of the two 4000 hp helium compressors are given in Table I. These compressors, originally used for air service, had to be reconditioned and converted to helium service. The existing compressors were five stage, six cylinder units, whereas the new design called for three stages, utilizing all existing cylinders, with adjusted interstage pressures to allow maximum mass flow throughput. To accomplish this, it was necessary to combine the cylinders into three stages and to unload the crank end of one of the first stage cylinders by removing the three suction valves and replacing the three discharge valves with blanks.

TABLE I

Design Characteristics of Compressors[1]

Unit Performance

Item	Stages of Compression		
	1	2	3
Cylinders Used	2 - 34¼"	1 - 27"	1 - 15" 1 - 9" 1 - 6"
Type of Gas	Helium		
Piston Displacement - cfm	7903	3268	1441.3
Compressor Speed - rpm	277		
Altitude	Sea Level		
Intake Temp. - °F	80	100	100
Intake Pressure - psia	15.435	38.57	87.97
Discharge Pressure - psia	39.337	89.73	180.81
Discharge Temp. - °F	325	325	287
Volumetric Eff. - %	84.88	85.28	84.95
Actual Capacity - cfm	6708	2787	1224.4
Equiv. Capacity - #/hr Dry	4286.5	4286.5	4286.5
Bhp/stage	610.7	536.3	501.8

The pistons were modified to accept graphite carbon-filled Teflon rider rings - two per piston. The rest of the compressor was rebuilt and used in its original form.

The Helium Gas Purification System

The gas purification system consists of two separate systems. One purifies the process flow whose main contaminant is oil, and the second purifies the compressor packing blow-by or seal gas which is contaminated by air and oil.

The compressor is lubricated with Rarus 427, which must be removed from the helium. This is done using a commercially bought full-flow oil mist removal system having a collection efficiency of 100% on all particles greater than 3 microns and 99.5% on particles less than 3 microns.

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The gas is then further purified in an activated carbon adsorber vessel containing 9000 lb of Type BPL 4×10 mesh granular activated carbon. Once it leaves the adsorber it is final filtered through a 2 micron cartridge filter before entering the cold box.

The seal gas purification system is designed to remove contaminants from the helium blow-by past the pistons. This gas is collected in the distance pieces which are at atmospheric pressure. The contaminated helium gas is then piped to the suction of a 280 scfm 265 psia screw compressor. This feeds a commercially bought cryogenic helium purifier, which reduces contamination level to 5 ppm air impurity for the first 12 hours and 25 ppm for the last 12 hours on stream before regeneration is necessary. The gas is then routed to discharge before the oil removal system and then to the cold box.

The Cold Box

The cold box is designed to accept 1268 g/sec of helium at 300°K and 12 atm and produce 4875 ℓ/hr at 4.6°K and 1.4 atm.[2] The first stage of cooling is provided by liquid nitrogen counter flowing with high pressure helium. Not more than .64 ℓ of nitrogen will be used for each liter of liquid helium produced. The flow divides with 916 g/sec going to the turbines and 351 g/sec to the high pressure side of the heat exchangers. Of the turbine flow all is expanded in turbine #1. The flow is divided again and 471 g/sec goes to turbine #2, with the remainder going to turbine #3. The 351 g/sec of high pressure helium is cooled to 6.2°K by return helium flow in heat exchangers 3 through 8. By means of a J-T valve, it is then expanded to 1.4 atm at 4.6°K. Figure 1 shows the T-S diagram.

The liquid-gas mixture passes through a phase separator, 194 g/sec of cold gas is returned to the low pressure side of the cold box and 157 g/sec of liquid collects in a 5000 gallon dewar. From the dewar the helium will be pumped to each of the 24 satellites and subsequently distributed to the Ring. The satellites use the liquid for lead cooling and satellite "boosting". The boosting results in 690 watts of 4.9°K refrigeration being delivered to the magnets from each satellite. In addition, the helium liquid is warmed to ambient, recompressed to 12 atm, and returned to the high pressure inlet of the cold box (see Figure 2, Helium Flow Diagram). This system has the advantage of extracting the available refrigeration from the stream at the satellite location, reducing the size and cost of the necessary transfer lines.

Construction Schedule

The main purpose of this facility is to supply the Fermilab Energy Doubler magnets with adequate liquid helium.

The construction schedule of the central liquefier, which is twice the size of any existing facility, calls for a performance test in 1979. The compressors were tested individually in early 1979 and met specifications. The major work on the purification system and on the cold box is complete. After the cold box performance test emphasis will shift to providing increased liquid and gas storage and to the construction of a closed loop liquid nitrogen plant to supply the needs of the central helium liquefier and the superconducting magnets.

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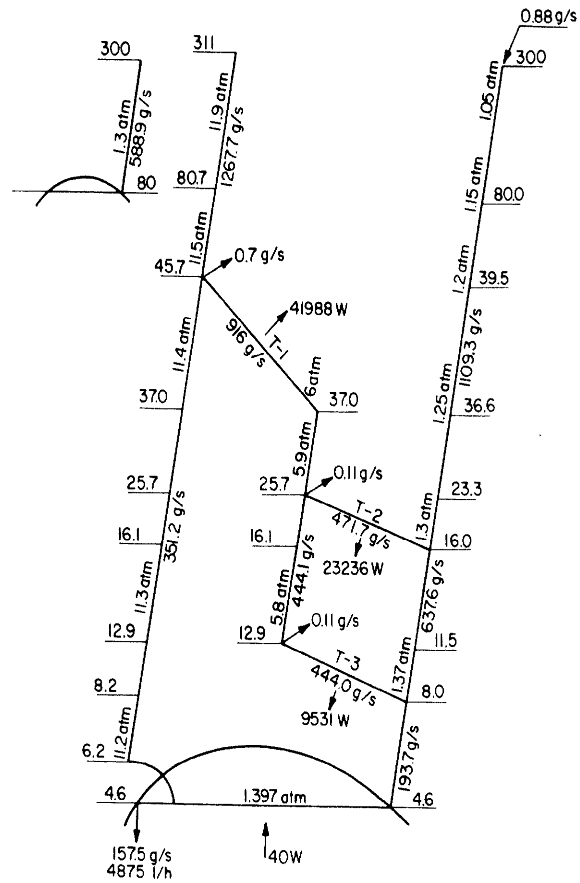


FIGURE 1. TS DIAGRAM

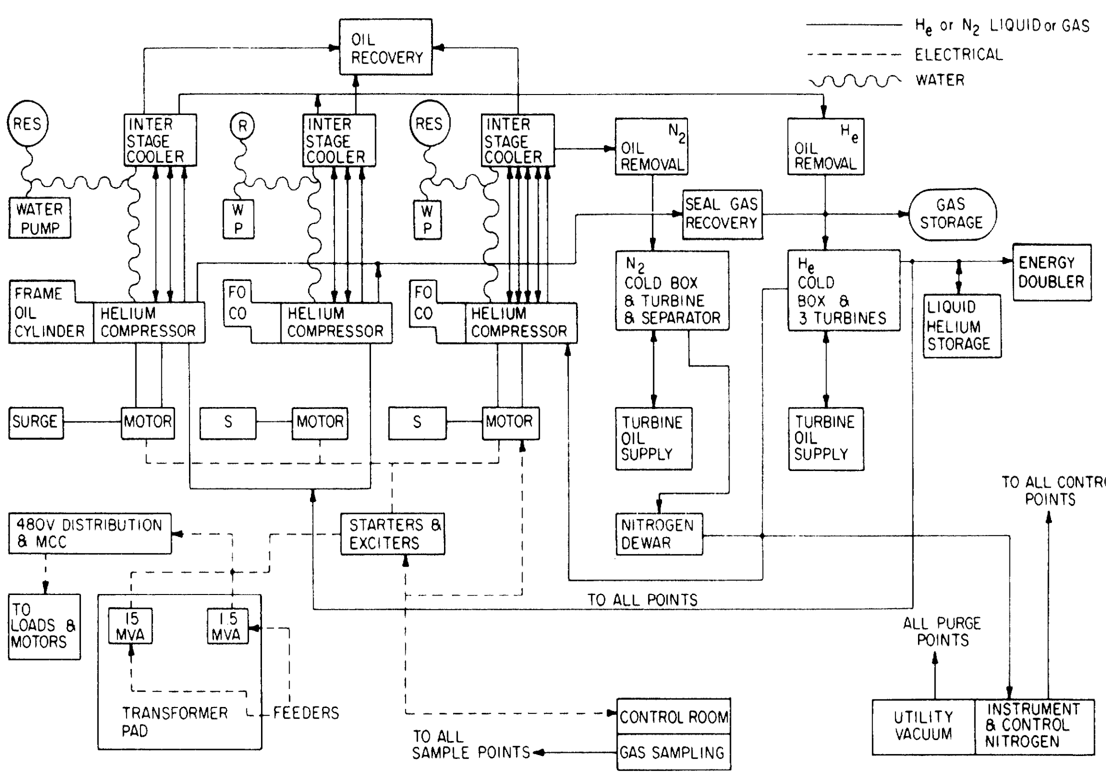
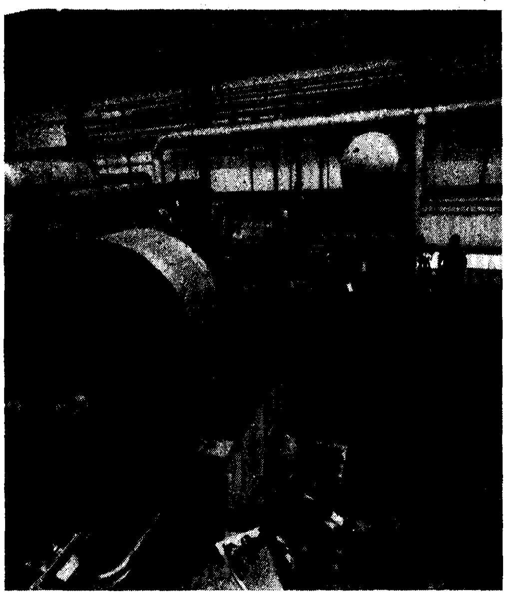
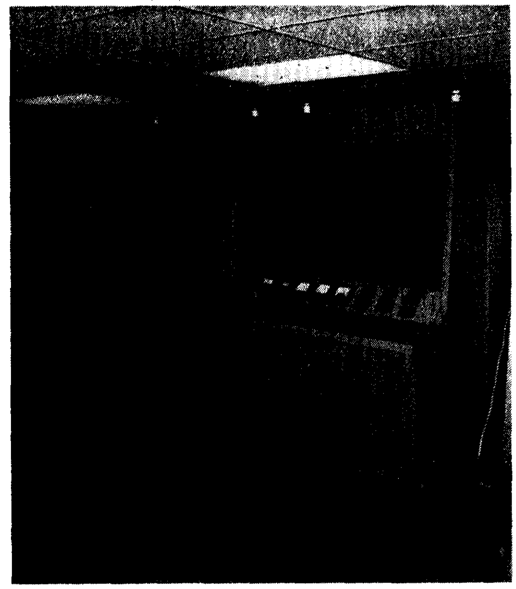


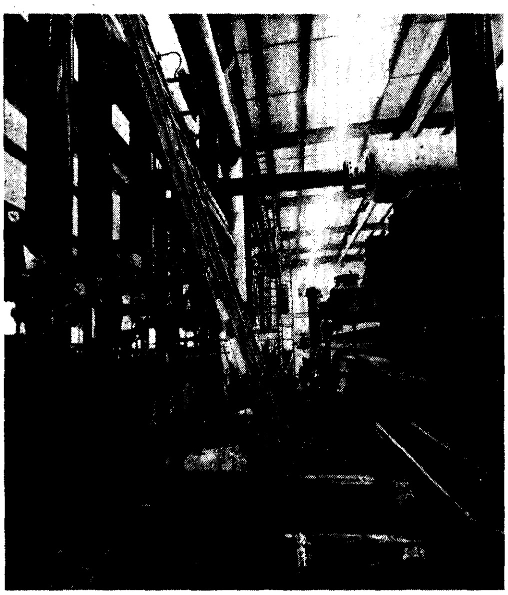
FIGURE 2. HELIUM FLOW DIAGRAM



Elliott 4000 hp Synchronous Motor and Worthington BDC Helium Compressor



Compressor and Cold Box Control Consoles



Helium Plant Compressor Piping

Cold Box and Turbine Oil Skid

References

1. C.R.Williams, Report for Design Engineering and Equipment Modification for Conversion of 4000 Bhp BDC-5 Air Compressor to Helium Service, Dec. 1, 1976

2. Helix Process Systems, Operator's Manual for Central Helium Reliquefier, May 1978